DOE/NE-ID-11229
Revision 0

U.S. Department of Energy
Idaho Operations Office

Monitored Natural Attenuation Interim Remedial Action Report, Test Area North, Operable Unit 1-07B

August 2005

Idaho Cleanup Project

DOE/NE-ID-11229
Revision 0
Project No. 23339

Monitored Natural Attenuation Interim Remedial Action Report, Test Area North, Operable Unit 1-07B

August 2005

Prepared for the
U.S. Department of Energy
Idaho Operations Office

ABSTRACT

This report is an interim remedial action report for the monitored natural attenuation remedial component of Operable Unit 1-07B at Test Area North at the Idaho National Laboratory Site. Under U.S. Environmental Protection Agency guidance, an interim report for long-term groundwater remedial action provides a description of the remedial component, information pertaining to operational and functional determination, a summary of project costs, observations and lessons learned, and contact information. It is the conclusion of this report that progress has been made toward the operational and functional determination requirements, as stated in the *Monitored Natural Attenuation Remedial Action Work Plan for Test Area North Final Groundwater Remediation, Operable Unit 1-07B*. This progress includes implementation of the monitored natural attenuation remedy since October 2003, evaluation of concentration data and trends, and direct and indirect evidence of the aerobic cometabolic degradation mechanism.

CONTENTS

FIGURES

TABLES

ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
COC	contaminant of concern
DCE	dichloroethene
DEQ	(Idaho) Department of Environmental Quality
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy Idaho Operations Office
EPA	U.S. Environmental Protection Agency
ESD	explanation of significant differences
FLUTe™	Flexible Liner Underground Technology
FY	fiscal year
ICP	Idaho Cleanup Project
INEEL	Idaho National Engineering and Environmental Laboratory
INEL	Idaho National Engineering Laboratory
INFO	for information
INL	Idaho National Laboratory
ISB	in situ bioremediation
MCL	maximum contaminant level
MNA	monitored natural attenuation
NPTF	New Pump and Treat Facility
OU	operable unit
PCE	tetrachloroethene
QA	quality assurance
QC	quality control
RAO	remedial action objective

RD/RA	remedial design/remedial action
ROD	Record of Decision
TAN	Test Area North
TCE	trichloroethene
TSF	Technical Support Facility
USC	*United States Code*
VC	vinyl chloride
VOC	volatile organic compound

Monitored Natural Attenuation Interim Remedial Action Report, Test Area North, Operable Unit 1-07B

1. INTRODUCTION

Monitored natural attenuation (MNA) is one of three remedial components currently being implemented for groundwater cleanup efforts associated with Operable Unit (OU) 1-07B at Test Area North (TAN) of the Idaho National Laboratory (INL) Site, which was previously called the Idaho National Engineering and Environmental Laboratory (INEEL). As part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remediation activities (42 USC § 9601 et seq.), MNA was selected as the remedy for the distal zone of the contaminant plume. Agency inspection and approval to commence MNA performance operations were completed as documented in the *Monitored Natural Attenuation Final Inspection Report* (ICP 2004).

As stated in the *Close-Out Procedures for National Priorities List Sites* (EPA 2000a), an Interim Remedial Action Report may be submitted for remedies involving groundwater restoration because of the long delay between signature of the Record of Decision (ROD) and achievement of the cleanup goals. The purpose of this Interim Remedial Action Report is to provide information that demonstrates progress toward determination that the MNA remedial component is operational and functional. This report, which is written to include components required by U.S. Environmental Protection Agency (EPA) guidance (EPA 2000a, 2001), is organized into the following sections:

- Introduction (Section 1)
- Description of the MNA remedial component (Section 2)
- Operational and functional determination (Section 3)
- Summary of project costs and enforceable milestones (Section 4)
- Observations and lessons learned (Section 5)
- Contact information (Section 6)
- References (Section 7).

1.1 Purpose

Pursuant to CERCLA regulations, "a remedy becomes 'operational and functional' either 1 year after construction is complete or when the remedy is determined concurrently by EPA and the state to be functioning properly and is performing as designed, whichever is earlier" (40 CFR 300.435 [f][2]). For the MNA remedial component, the operational and functional determination requirements are stated in the *Monitored Natural Attenuation Remedial Action Work Plan for Test Area North Final Groundwater Remediation, Operable Unit 1-07B* (DOE-ID 2003a) and restated in Section 3 of this report. Since not enough data have been collected to make the determination that the MNA remedy is operational and functional, the purpose of this Interim Remedial Action Report is to present data showing progress toward the operational and functional determination for the MNA remedy.

1.2 Regulatory Background

From about 1953 to 1972, activities conducted at TAN generated liquid waste that was disposed of by direct injection into the TSF-05 injection well located in the southwest corner of the Technical Support Facility (TSF). This well dispersed the waste into the Snake River Plain Aquifer, which underlies INL. The waste consisted mainly of industrial and sanitary wastewater but also included organic, inorganic, and low-level radioactive wastewaters. Activities generating this waste included efforts to develop a nuclear-powered aircraft and tests simulating accidental loss of coolant from nuclear reactors. Contamination was discovered in 1989 and was first addressed in accordance with the *Consent Order and Compliance Agreement* (DOE-ID 1987). In 1991, the EPA, U.S. Department of Energy (DOE), and the Idaho Department of Health and Welfare (presently named the Idaho Department of Environmental Quality [DEQ]) (i.e., the Agencies) entered into the *Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory* (DOE-ID 1991). As a result, contaminated groundwater that emanates from TSF-05 was designated as OU 1-07B.

A remedial investigation/feasibility study was completed (INEL 1994), which led to the approval of the *Record of Decision Declaration for the Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites Final Remedial Action* (DOE-ID 1995). This ROD included a default remedy of pump and treat; however, it allowed for additional treatability studies to be performed in order to determine if a more cost-effective remedy could be identified. Site characterization in conjunction with the treatability studies made it evident that the most cost-effective way to treat a contaminant plume as large and complex as the TAN plume was to divide it into three different zones with separate remedial components for each zone. The three zones—defined based on the extent of trichloroethene (TCE) concentrations—include the hot spot, the medial zone, and the distal zone. This distinction regarding the approach to the plume-wide cleanup process was documented in the *Explanation of Significant Differences from the Record of Decision for the Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites, Final Remedial Action, Operable Unit 1-07B, Waste Area Group 1* (INEEL 1997).

Completion of the treatability study process identified MNA as an efficient and more cost-effective remedy for the distal zone than the default pump-and-treat remedy. Therefore, MNA was selected as the final remedy for that zone in the *Record of Decision Amendment Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites, Final Remedial Action* (DOE-ID 2001).

1.3 Test Area North Operable Unit 1-07B Description

Operable Unit 1-07B is the final remedial action for the TSF-05 injection well and the surrounding groundwater contamination located within TAN, which is one of nine major facilities at the INL Site (Figure 1). The TAN contaminant plume originates from the TSF-05 injection well, which is 93 m (310 ft) deep and is perforated from 55 to 74 m (180 to 244 ft) and 82 to 93 m (269 to 305 ft) below ground surface. Historical records provide little definitive information on the types and volumes of organic waste disposed of into the groundwater via the injection well. It is estimated that as little as 1,325 L (350 gal) or as much as 132,489 L (35,000 gal) of TCE might have been disposed of using the injection well during its operational period. Table 1 is a list of contaminants of concern (COCs) in the vicinity of TSF-05 that were established in the 1995 ROD (DOE-ID 1995).

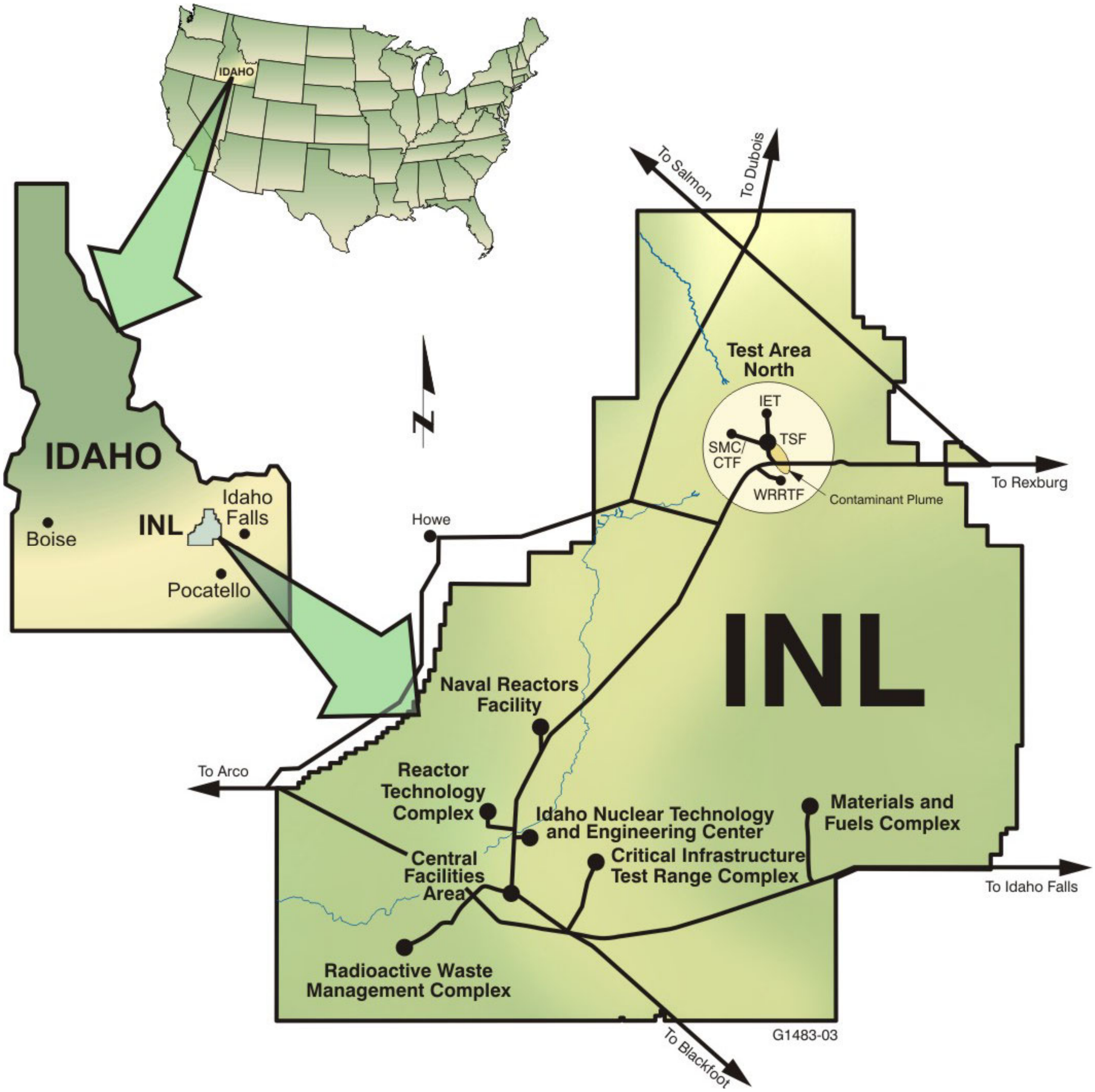

Figure 1. Map of the Idaho National Laboratory Site showing the location of major facilities and Test Area North.

Table 1. Contaminants of concern in the vicinity of the TSF-05 injection well (established in the 1995 Record of Decision).

Contaminant	Maximum Concentrations[a]	Federal Drinking Water Standard
Volatile Organic Compounds		
TCE	12,000–32,000 ppb[b]	5 ppb[c]
PCE	110 ppb	5 ppb[c]
cis-1, 2-DCE	3,200–7,500 ppb	70 ppb[c]
trans-1, 2-DCE	1,300–3,900 ppb	100 ppb[c]
Radionuclides		
Tritium	14,900–15,300 pCi/L[d]	20,000 pCi/L
Strontium 90	530–1,880 pCi/L	8 pCi/L
Cesium-137	1,600–2,150 pCi/L	119 pCi/L[e]
Uranium-234	5.2–7.7 pCi/L[d]	27 pCi/L[f]

ppb = parts per billion pCi/L = picocuries per liter

a. The concentration range is taken from measured groundwater concentrations at the TSF-05 injection well (INEEL 1999).
b. Higher TCE concentrations were detected during Phase A surge-and-stress pumping of the TSF-05 injection well.
c. ppb is a weight-to-weight ratio that is equivalent to micrograms per liter (µg/L) in water.
d. Maximum concentrations of tritium and U-234 are below federal drinking water standards and baseline risk calculations indicate a cancer risk of 3×10^{-6}. While this risk is smaller than 1×10^{-4}, both tritium and U-234 are included as COCs as a comprehensive plume management strategy.
e. The maximum contaminant level for Cs-137 is derived from a limit of 4 mrem/yr cumulative dose equivalent to the public, assuming a lifetime intake of 2 L/day of water.
f. The federal drinking water standard for U-234 is for the U-234, U-235, and U-238 series.

COC = contaminant of concern
DCE = dichloroethene
PCE = tetrachloroethene
TCE = trichloroethene

1.4 Overall Remedial Action Summary

The final remedy for OU 1-07B combines in situ bioremediation (ISB) for hot spot restoration and MNA for distal zone restoration with pump-and-treat for the medial zone (DOE-ID 1995), providing a comprehensive approach to the restoration of the contaminant plume. The following is a description of the remedy components for restoration of the OU 1-07B hot spot, medial zone, and distal zone of the contaminant plume (illustrated conceptually in Figure 2) and the institutional controls, monitoring, and contingencies for each remedy.

- **Hot Spot**—The selected remedial component for the hot spot is ISB, which promotes bacterial growth by supplying essential nutrients to indigenous bacteria that are able to break down contaminants within the aquifer. An amendment (i.e., sodium lactate or whey powder) is injected into the secondary source area through the TSF-05 injection well or through other injection wells in the immediate vicinity. Amendment injections stimulate the growth and activity of bacteria, thereby increasing the rate at which the volatile organic compounds (VOCs) break down into harmless compounds. The amendment supply is distributed as needed, and the treatment system operates year-round.

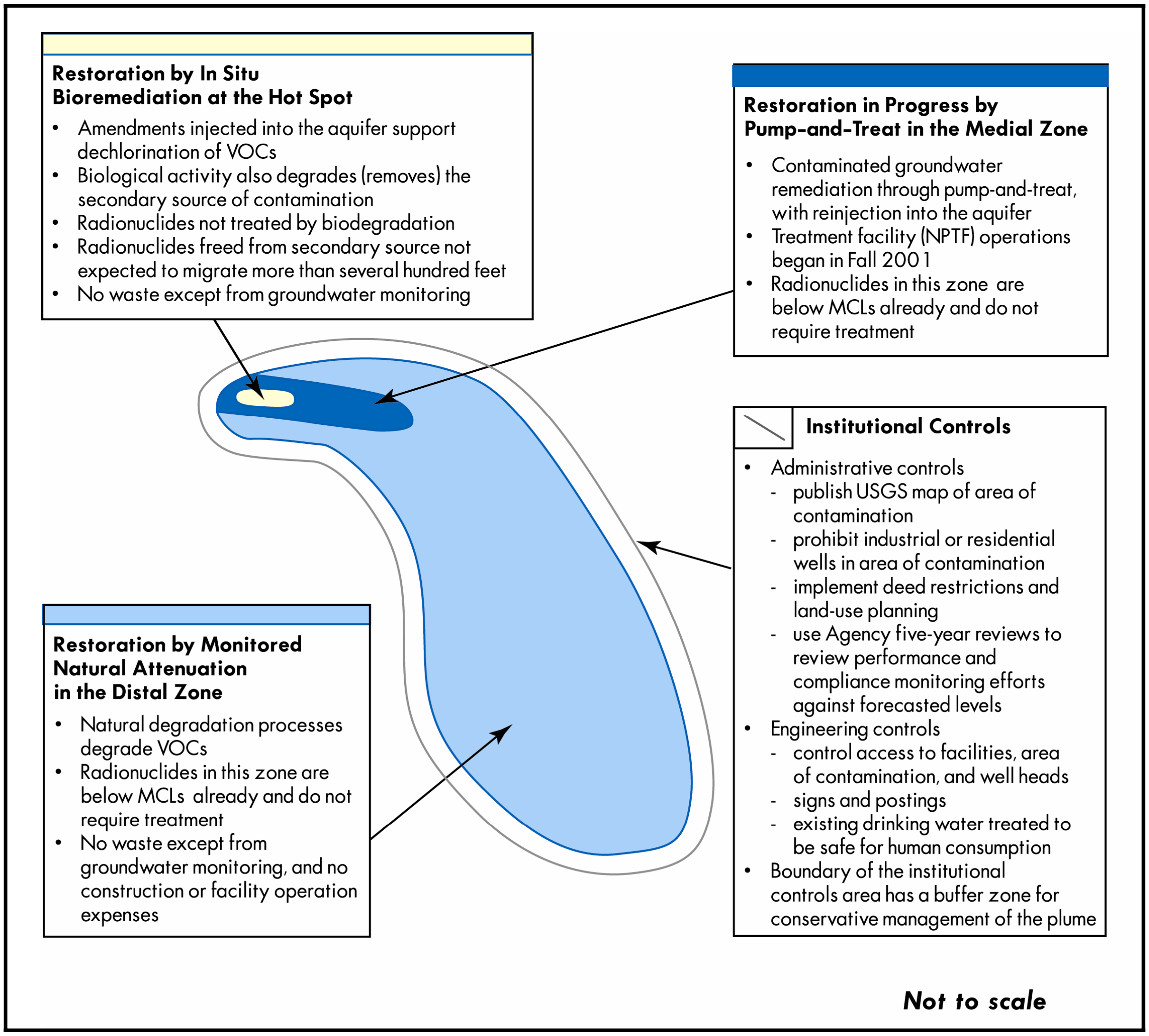

Figure 2. Conceptual illustration of the remedial action components.

- **Medial Zone**—The selected remedial component for the medial zone is pump-and-treat. Pump-and-treat involves extraction of contaminated groundwater, treatment through air strippers, and injection of treated groundwater back into the aquifer. In accordance with the original remedy selected in the ROD (DOE-ID 1995), construction of the New Pump and Treat Facility (NPTF) in the medial zone was completed in January 2001. Routine operations for the NPTF began on October 1, 2001. The Agencies approved a medial zone rebound test to evaluate the effectiveness of the NPTF. The NPTF was shut down on March 1, 2005, and the duration of this rebound test is approximately 24 months.

- **Distal Zone**—The selected remedy component for the distal zone is MNA. Natural attenuation is the physical, chemical, and biological processes that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. Monitored natural attenuation includes groundwater monitoring to compare actual measured degradation rates to predicted degradation rates.

- **Institutional Controls**—Engineering and administrative controls have been put in place to protect current and future users from health risks associated with groundwater contamination. Groundwater monitoring and numerical modeling will be used to track the plume boundary. The institutional controls area will be modified, as required, to maintain a conservative buffer zone around the contaminant plume area.

- **Monitoring**—Groundwater monitoring is conducted throughout the plume with samples analyzed to determine the progress of the remedy.

- **Contingencies**—Contingencies identified under the remedy include:

  - For the medial zone, monitoring wells located upgradient of the NPTF will be monitored on a routine basis to ensure that concentrations of radionuclides in the groundwater remain low. If monitoring indicates that the concentration of radionuclides in the NPTF effluent would exceed maximum contaminant levels (MCLs), then the Air Stripper Treatment Unit—located between the hot spot and the NPTF (but not currently operating)—will be used to prevent those radionuclides from traveling downgradient to the NPTF.

  - For the distal zone, if the Agencies determine that MNA will not restore the distal zone of the plume within the restoration timeframe, pump-and-treat units will be designed, constructed, and operated in the distal zone to remediate the plume. This contingency remedy also will be invoked if the required monitoring necessary for MNA is not performed.

Under the final remedy for OU 1-07B, the concentrations of the radionuclide COCs in the hot spot and medial zone will meet the remedial action objectives (RAOs) stated in the ROD within the remedial timeframe through natural attenuation processes. Concentrations of the radionuclide COCs in the distal zone have never exceeded the RAOs. The groundwater monitoring program will include monitoring the attenuation of radionuclide COCs in the hot spot and the medial zone.

1.5 Scope of the Monitored Natural Attenuation Remedial Action

The MNA Remedial Action Work Plan (DOE-ID 2003a) outlines a process that follows the governing CERCLA (42 USC § 9601 et seq.) and Federal Facility Agreement and Consent Order requirements (DOE-ID 1991) for implementing MNA as the remedial action for the distal zone at TAN. This process integrates project team input and Agency input at critical milestones in accordance with the *Remedial Design/Remedial Action Scope of Work Test Area North Final Groundwater Remediation Operable Unit 1-07B* (DOE-ID 2002). This remedial action was developed in concert with several supporting reports to document the basis for long-term MNA operations. This section provides background and a description of the MNA remedial component, including performance and compliance objectives (Section 1.5.1), the implementation strategy (Section 1.5.2), governing documents (Section 1.5.3), and chronology of events (Section 1.5.4).

1.5.1 Performance and Compliance Objectives

The performance and compliance monitoring objectives for MNA consist of demonstrating meaningful progress toward restoring the distal zone of the contaminated aquifer groundwater by 2095 (100 years from the signature of the ROD [DOE-ID 1995]) by reducing all COCs to below MCLs and a 1×10^{-4} total cumulative carcinogenic risk-based level for future residential groundwater use, and until the cumulative hazard index is less than 1 for noncarcinogens. These objectives will be met by collecting monitoring data that demonstrate restoration of the plume by 2095.

As stated in the MNA Remedial Action Work Plan (DOE-ID 2003a), performance objectives consist of the following:

- Monitoring whether the natural attenuation process continues to trend toward the RAOs for the distal zone of the plume
- Monitoring plume expansion.

Compliance objectives consist of the following:

- Conducting groundwater monitoring at all MNA performance-monitoring wells at a frequency and duration sufficient to demonstrate that the remedy is operational, functional, and effective
- Demonstrating at the end of the remedial action period that RAOs for groundwater have been attained.

1.5.2 Implementation Strategy

The MNA implementation strategy for the distal zone, as defined in the MNA Remedial Action Work Plan (DOE-ID 2003a), is to divide the groundwater plume into three distinct monitoring zones (Zones 1 through 3) and two operational phases (performance and long-term). This division allows for staggered transitions from performance operations into long-term operations for each zone. The boundary of each monitoring zone is based on the expected time that will be required to identify concentration trends for wells within that zone and to confirm that TCE is being transported and degraded as expected. The year when peak TCE concentration will occur (which is referred to as the peak contaminant breakthrough for TCE) was estimated for the MNA monitoring wells using results from numerical modeling. The performance objectives (stated in Section 1.5.1) include monitoring whether the natural attenuation process continues to trend toward the RAOs for the distal zone of the plume. As data are collected for the MNA monitoring wells, TCE concentrations will be compared to the predicted peak contaminant breakthrough to confirm that TCE is being transported and degraded as expected. It is not expected that observed monitoring data will exactly match the predictions, but analysis of the data will be conducted to confirm that peak contaminant breakthrough of TCE has occurred at a time sufficient to meet the RAOs.

Based on the peak contaminant breakthroughs for the MNA monitoring wells, the distal portion of the plume was divided into three zones (Figure 3). Zone 1 is the upgradient portion of the plume where peak contaminant breakthrough is thought to have already occurred based on previous modeling studies. In Zone 1, confirmatory data are expected to be obtained within approximately 10 years. Zone 2 is the downgradient portion of the plume where confirmatory concentration trends might require 20 years or more to collect, owing to long travel times from the upgradient source. Zone 3 is the area outside the downgradient extent of the plume where groundwater data will be used to monitor plume expansion.

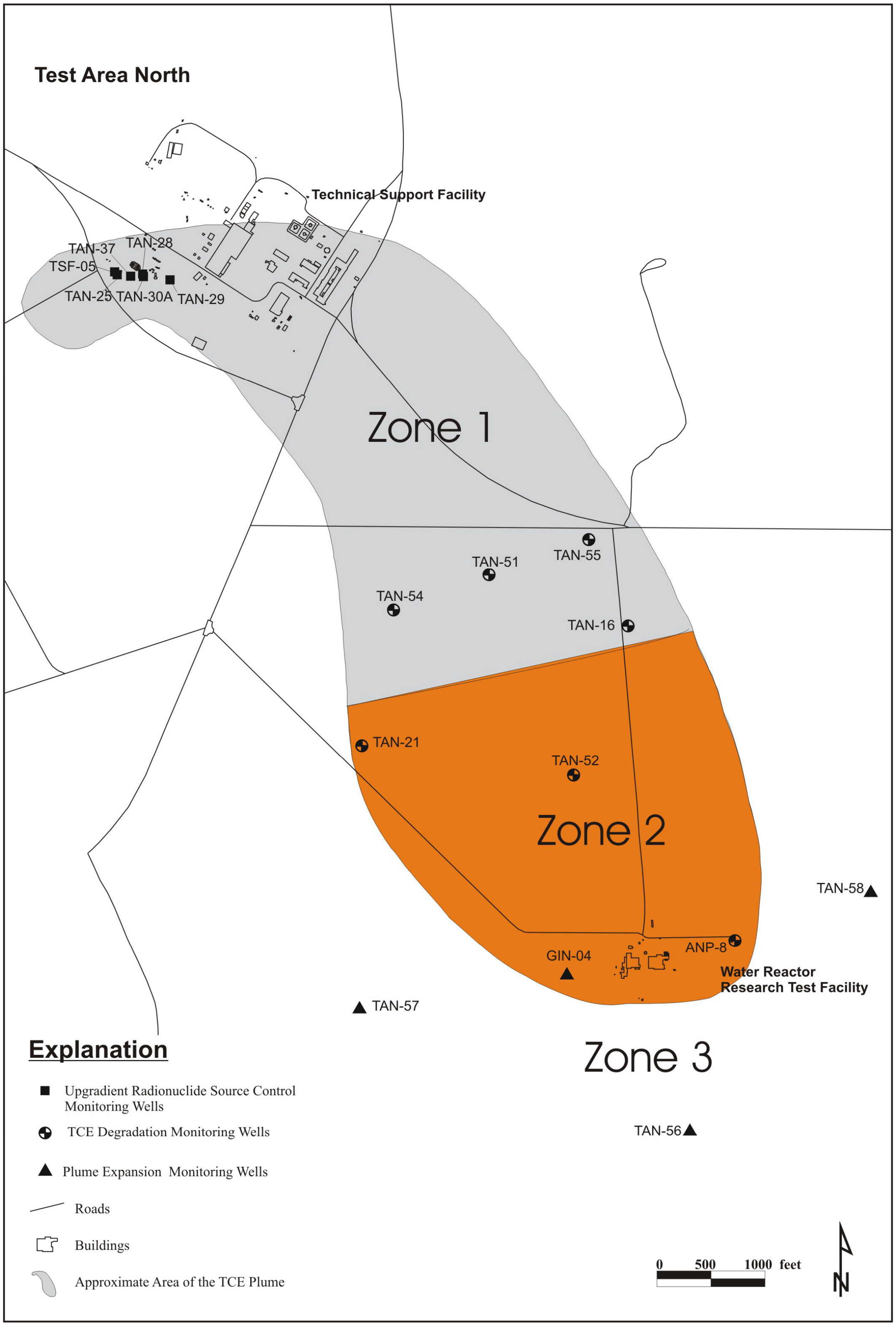

Figure 3. Approximate extent of the Test Area North trichloroethene plume with monitored natural attenuation monitoring-zone divisions.

The sequence for MNA operations is illustrated in Figure 4. The MNA implementation will be performed under the two operational phases, as follows:

- **Performance Operations**—This phase consists of a period of annual sampling and analysis activities to confirm that TCE is being transported and degraded. The duration of this phase is variable, based on the results of the data collected.

- **Long-Term Operations**—This phase will consist of periodic groundwater monitoring for the duration of the remedial action period to track the remedy's progress toward achieving the RAOs.

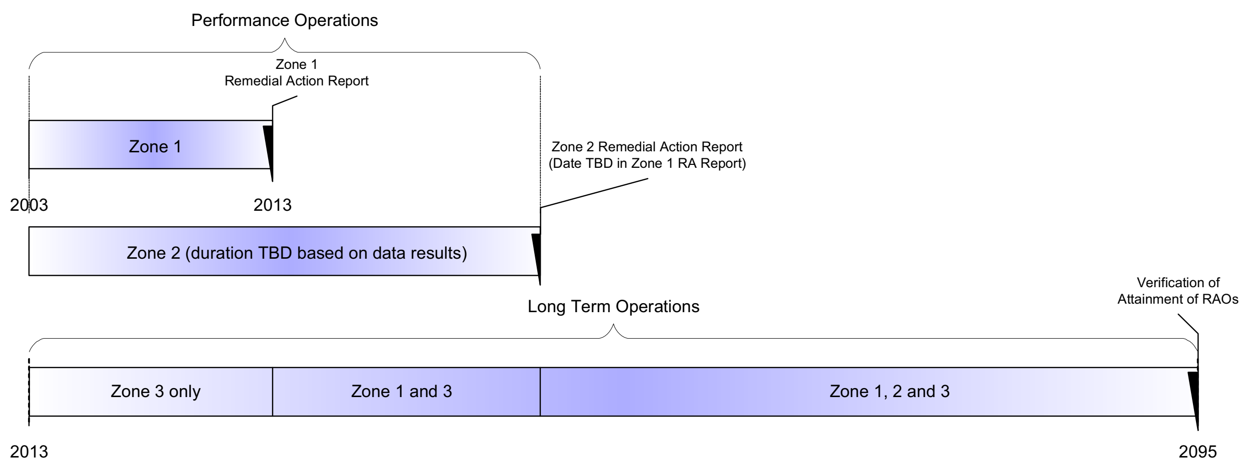

Figure 4. Summary illustration of the remedial action operational phases for monitored natural attenuation.

1.5.3 Governing Documents

The MNA Remedial Action Work Plan (DOE-ID 2003a) outlines the process for implementing MNA at TAN and was developed in concert with several supporting documents to establish the basis for MNA operations. It identifies and establishes the applicable or relevant and appropriate requirements, the technical basis for selection of MNA, the technical assessment of MNA, infrastructure, and the requirements for operation, monitoring, and reporting. Supporting documentation provides technical methods, procedures, and protocols for implementing the requirements. Other documents that govern implementation of MNA include:

- *Monitored Natural Attenuation Operations, Monitoring, and Maintenance Plan for Test Area North, Operable Unit 1-07B* (DOE-ID 2003b)

- *Test Area North Operable Unit 1-07B Final Groundwater Remedial Action Health and Safety Plan* (ICP 2005a)

- *Interim Decontamination Plan for Operable Unit 1-07B* (INEEL 2002)

- *Waste Management Plan for Test Area North Final Groundwater Remediation Operable Unit 1-07B* (ICP 2005b)

- *Quality Assurance Project Plan for Waste Area Groups 1, 2, 3, 4, 5, 6, 7, 10, and Deactivation, Decontamination, and Decommissioning* (DOE-ID 2004a).

1.5.4 Chronology of Events

A chronology of events for MNA is detailed in Table 2. The original remedy, described in the 1995 ROD (DOE-ID 1995) and refined in the Explanation of Significant Differences (ESD) (INEEL 1997), called for groundwater extraction and aboveground treatment for all three zones using three separate pump-and-treat facilities. The 1995 ROD was written with a requirement to conduct treatability studies to focus on specific technologies that offered the potential to be more cost effective than the original remedy.

Table 2. Timeline of events and documents relevant to monitored natural attenuation implementation.

Events	Date	Reference
Remedial Investigation	January 1994	INEL 1994
Record of Decision	August 1995	DOE-ID 1995
Technology Evaluation Work Plan	March 1997	DOE-ID 1997a
RD/RA Scope of Work	August 1997	DOE-ID 1997b
OU 1-07B Explanation of Significant Differences	November 1997	INEEL 1997
Field Evaluation Work Plan	September 1998	DOE-ID 1998
Field Demonstration Report	March 2000	DOE-ID 2000
Record of Decision Amendment	September 2001	DOE-ID 2001
RD/RA Scope of Work	November 2001	DOE-ID 2002
MNA Remedial Action Work Plan	October 2003	DOE-ID 2003a
MNA Operations, Monitoring, and Maintenance Plan	October 2003	DOE-ID 2003b
Model Verification Report	June 2003	INEEL 2003
MNA Pre-Final Inspection	October 2003	ICP 2004
MNA Final Inspection Report	October 2003	ICP 2004
Began Performance Operations	October 2003	ICP 2004
Projection for achieving RAOs	By 2095	DOE-ID 2003a

MNA = monitored natural attenuation
OU = operable unit
RAO = remedial action objective
RD/RA = remedial design/remedial action

A *Technology Evaluation Work Plan Test Area North Final Groundwater Remediation Operable Unit 1-07B* (DOE-ID 1997a) was established, which governed evaluation of alternatives. The results of the treatability studies, which were concluded in 1999 and summarized in the *Field Demonstration Report, Test Area North Final Groundwater Remediation, Operable Unit 1-07B* (DOE-ID 2000), demonstrated that the MNA technology evaluation met or exceeded all objectives and expectations. The technical success of the field evaluation, combined with the preliminary cost information, supported a recommendation to implement MNA for remediation of the distal zone. Therefore, in 2001, a ROD amendment was written that selected MNA to replace pump-and-treat for the distal zone (DOE-ID 2001).

The MNA Remedial Action Work Plan (DOE-ID 2003a) details the technical basis for selecting MNA and the criteria for performing a technical assessment of MNA throughout the operational period to continually determine the remedy's effectiveness. The MNA Final Inspection Report (ICP 2004) led to commencement of MNA performance operations in October 2003. The MNA operations will continue according to the phased implementation strategy summarized in Section 1.5.2. As shown in Table 2, the RAOs for the MNA remedial component are projected to be achieved by 2095 (DOE-ID 2003a), 100 years from the signature of the 1995 ROD. The ROD Amendment states that if evaluations show that the RAOs will not be met within this restoration timeframe, then the contingency remedy will be implemented. Evaluation of MNA implementation with regard to the compliance and performance objectives stated in the MNA Remedial Action Work Plan (DOE-ID 2003b) demonstrates that the MNA component is operating as expected; therefore, the projected timeframe stated in the ROD Amendment has not been modified.

2. DESCRIPTION OF THE MONITORED NATURAL ATTENUATION REMEDIAL COMPONENT

The MNA remedial component includes infrastructure and monitoring programs necessary to achieve the MNA remedial component objectives. This section includes a description of the infrastructure, including the monitoring well network, well drilling and construction activities, and well maintenance. This section also provides a summary of the MNA monitoring program, waste management activities, institutional controls, and the final inspection.

2.1 Infrastructure

Specific sets of wells for the MNA monitoring zones (as shown in Figure 3) were identified in the MNA Remedial Action Work Plan (DOE-ID 2003a) to support the goals and objectives of MNA groundwater monitoring. This section discusses the monitoring well network, well drilling and construction activities, and the well maintenance strategy.

2.1.1 Monitoring Well Network

As stated in the MNA Remedial Action Work Plan (DOE-ID 2003a), the following wells are included in the monitoring well network for each zone:

- **Zone 1—**Performance-monitoring wells include TAN-16, TAN-51, TAN-54, and TAN-55 for VOC contaminants and TAN-25, TAN-28, TAN-29, TAN-30A, TAN-37, and TSF-05 for radionuclide contaminants. Monitoring of VOC contaminants is performed to determine whether peak TCE concentration breakthrough has occurred at these wells, as predicted by numerical modeling. Monitoring of radionuclide contaminants is performed to verify that concentrations combined with radioactive decay and observed rates of attenuation will be below MCLs before 2095.

- **Zone 2—**Performance-monitoring wells include TAN-52, TAN-21, and ANP-8 for VOC contaminants and tritium. Monitoring of VOC contaminants is performed to identify whether wells in this zone exhibit peak TCE concentration breakthroughs, as predicted by numerical modeling.

- **Zone 3—**Performance-monitoring wells include GIN-4, TAN-56, TAN-57, and TAN-58 for VOC contaminants. Monitoring is performed to verify that the plume does not expand axially more than 30% beyond the downgradient extent of the 5-µg/L isopleth.

2.1.2 Well Drilling and Construction Activities

All wells included in the MNA monitoring well network were installed prior to implementation of the MNA Remedial Action Work Plan (DOE-ID 2003a). Five MNA wells (TAN-51, TAN-52, TAN-54, TAN-55, and TAN-56) were fitted with Flexible Liner Underground Technology (FLUTe^{TM}) liners to facilitate sampling at multiple depths. A summary of well construction information is provided in the MNA Operations, Monitoring, and Maintenance Plan (DOE-ID 2003b). Future construction activities that may occur during the MNA remedy include installation of additional monitoring wells, FLUTe^{TM} liners, or dedicated sampling equipment in accordance with project plans and specifications.

2.1.3 Well Maintenance

Details for well maintenance activities are stated in the MNA Operations, Monitoring, and Maintenance Plan (DOE-ID 2003b) and are summarized herein. Maintenance and repair activities will be performed (as needed) when equipment failure or changes in the operating characteristics of the well, pump, or other installed equipment prevents attainment of program objectives. At a minimum, inspections and maintenance will include surface (e.g., cement pad and locking mechanism) and subsurface (e.g., pump and electrical wiring) inspections. Maintenance schedules are developed using collected inspection information, manufacturers' recommendations, historical data, and reports of deteriorating performance.

2.2 Monitored Natural Attenuation Groundwater Monitoring Program

In order to meet the objectives of the MNA remedial component, the MNA groundwater monitoring program is designed to collect groundwater samples to assess the remedy's performance. The monitoring program is designed to meet data quality objectives developed for the MNA remedial component, which are presented in detail in the MNA Remedial Action Work Plan (DOE-ID 2003a). The data quality objectives, which were prepared following the *Guidance for the Data Quality Objectives Process* (EPA 2000b), included consideration of information gathered for the technical assessment of MNA, the RAOs, the spatial boundaries of the distal zone, the remediation timeframe, and experience with sampling and analysis methods required to support decisions on remedy performance.

Data quality requirements for all INL CERCLA investigations and remedial responses are defined in the MNA Operations, Monitoring, and Maintenance Plan (DOE-ID 2003b) and the INL Quality Assurance Project Plan (DOE-ID 2004a). The Quality Assurance (QA)/Quality Control (QC) requirements are implemented to assess the overall quality of the sampling and analysis program. This includes field QC samples (field blanks, trip blanks, and field duplicates) and laboratory QA samples (blanks, standards, duplicates, standard reference materials, and matrix spikes). In addition, requirements are established for the precision of duplicate samples, the accuracy of standards and matrix spikes, and the completeness of samples collected.

A summary of the monitoring program is presented in this section and a more complete description is stated in the MNA Operations, Monitoring, and Maintenance Plan (DOE-ID 2003b). During performance operations, groundwater samples will be collected from a set of wells within each of the three zones. Table 3 summarizes the zone, sampling frequency, monitoring location, and analyte list for performance operations. Monitoring well information, including well construction details, sampling depths, and water levels, is detailed in Appendix A of this report. The goal of collecting VOC data from Zone 1 and 2 monitoring wells is to determine the timing of peak TCE concentration breakthrough in comparison to numerical modeling predictions. Radionuclide samples are collected from Zone 1 wells to verify natural attenuation of radionuclides. The VOC data are collected from Zone 3 wells to monitor plume expansion.

Five MNA monitoring wells are equipped with FLUTe^{TM} liners to allow samples to be collected at specific depths in the aquifer (Section 2.1.2). Data collection at different depths provides information about the vertical distribution of contaminants in the aquifer. The goal of using this sampling design is to identify the presence or absence and possible trends in VOC and radionuclide concentrations with respect to depth.

Table 3. Summary of the monitoring requirements for performance operations.

Zone	Frequency	Location	Parameters
1	Annual	TAN-16, TAN-51[a], TAN-54[a], and TAN-55[a]	TCE, PCE, cis- and trans-DCE, VC, and tritium
		TAN-25, TAN-28, TAN-29, TAN-30A, TAN-37[a], and TSF-05[a]	Gross alpha, Sr-90, Cs-137, and tritium
2	Annual	TAN-52[a], TAN-21, and ANP-8	TCE, PCE, cis- and trans-DCE, VC, and tritium
3	Every 3 years	GIN-4, TAN-56[a], TAN-57, and TAN-58	TCE, PCE, cis- and trans-DCE, VC, and tritium

a. Well is sampled at multiple depths. See Appendix A for details.

DCE = dichloroethene
PCE = tetrachloroethene
TCE = trichloroethene
VC = vinyl chloride

2.3 Waste Management

The MNA Remedial Action Work Plan (DOE-ID 2003a) addresses the requirements for all waste generated during operation of the MNA remedy. The waste expected to be generated during MNA operations include:

- Resource Conservation and Recovery Act-listed waste (42 USC § 6901 et seq.)
- Low-level radioactive waste
- Personal protective equipment
- Sampling purge water.

All generated waste is identified, characterized, containerized, labeled, handled, stored, and disposed of in a manner consistent with the *Waste Management Plan for Test Area North Final Groundwater Remediation Operable Unit 1-07B* (ICP 2005b) and all other applicable requirements. The waste containers are inspected periodically, their locations are confirmed periodically, and the waste and inspection records are maintained.

2.4 Health and Safety

The *Test Area North Operable Unit 1-07B Final Groundwater Remedial Action Health and Safety Plan* (ICP 2005a) establishes the procedures and requirements used to eliminate or minimize health and safety risks to personnel. These procedures and requirements were developed to include elements of the INL Voluntary Protection Program and the Integrated Safety Management System criteria, principles, and concepts to identify and mitigate hazards, thereby preventing accidents. The Voluntary Protection Program is focused on the “people” aspect of conducting work and the Integrated Safety Management System focuses on the system side of conducting operations. No health and safety problems were encountered during implementation of the MNA remedial component. The required levels of personal protective equipment, site control, and security requirements are stated in the *Test Area North Operable Unit 1-07B Final Groundwater Remedial Action Health and Safety Plan* (ICP 2005a) for the various activities performed during MNA operations.

2.5 Institutional Controls

Institutional controls consist of engineering and administrative controls to protect current and future users from health risks associated with (1) ingestion or inhalation of, or dermal contact with, contaminants in concentrations greater than the MCLs; (2) contaminants with greater than a 1×10^{-4} cumulative carcinogenic risk-based concentration; or (3) a cumulative hazard index of greater than 1, whichever is more restrictive. The risk assessment is based on future residential use of this land. Institutional controls will be implemented until groundwater meets RAOs and unrestricted land use is allowed (DOE-ID 2001). The institutional controls for MNA are maintained in accordance with the *INEEL Sitewide Institutional Controls Plan* (DOE-ID 2004b). The Long-Term Stewardship Program is responsible for ensuring that the institutional controls are maintained (point of contact is Wendell Jolley [208] 526-5990).

Engineering controls, which include devices and controls to restrict access to water from within the contaminated plume (e.g., locking devices on wellheads), have been implemented. Administrative controls include postings on wellheads (identifying potential hazards) and placing written notification of this remedial action in the facility Land-Use Master Plan. A copy of the Land-Use Master Plan is available to the U.S. Bureau of Land Management, county planners, and other organizations that might be affected. The notification in the Land-Use Master Plan includes the following:

- Identification/map of the area of contamination; this map includes the institutional control boundary defining the anticipated 30% growth of the plume and an extra 10% buffer.

  The notification in the Land-Use Master Plan also either prohibits or requires the following:

- Prohibits installation of any drinking water and agricultural wells accessing the aquifer within the contaminated plume and buffer zone, as described in the ROD Amendment (DOE-ID 2001)

- Requires all wells within the plume boundaries to be locked and accessible only by program personnel

- Prohibits drilling or water use in the area approximately 2 mi south of TAN and requires program approval for any drilling near TAN

- Prohibits any activities that would interfere with the remedial activity.

2.6 Final Inspection

During the MNA prefinal inspection (which took place on October 16, 2003), it was determined that the MNA component was ready for operations. Therefore, the prefinal inspection became the final inspection. Inspection activities included a walk-through of the monitoring well network and a review of governing documents (described in Section 1.5.3). The MNA Final Inspection Report (ICP 2004) documents the prefinal inspection checklist items, discussion of prefinal inspection findings, action for correction of inspection findings, and the Agencies' concurrence that the MNA component meets the project's functional and operational requirements. The details of the completed corrective actions are stated in Appendix B of this report. Following this final inspection, MNA performance operations began.

3. OPERATIONAL AND FUNCTIONAL DETERMINATION

The MNA performance and compliance monitoring requirements outline the process by which the MNA remedial component is determined to be operational and functional. As stated in the MNA Remedial Action Work Plan (DOE-ID 2003a), the completion criteria requirements for determining when the remedy is operational and functional for Zones 1 and 2 are shown in Table 4. Zone 1 will be operational and functional when:

- Peak TCE breakthrough is exhibited in data before the numerical model-bounding estimate
- Radiological data indicate attenuation sufficient to meet the RAOs.

Zone 2 will be operational and functional when peak TCE breakthrough is exhibited in data before the numerical model-bounding estimate. Alternatively, the Agencies may determine Zone 2 to be operational and functional when the following occurs:

- Zone 1 performance and operations are complete
- A biodegradation mechanism has been demonstrated.

Following operational and functional determination for Zones 1 and 2, the operational phase will transition from performance operations to long-term operations. Confirmation of predicted contaminant trends will occur throughout performance operations. Future recommendations for changes to the MNA monitoring requirements during performance operations will be stated in MNA Annual Reports. Long-term operations will confirm that the remedy meets the RAOs.

The MNA component has been in operation since completion of the final inspection in October 2003; however, data collected before October 2003 are available for most of the MNA monitoring wells. A summary of progress made toward determining the operational and functional status of the MNA remedial component includes the following:

- The MNA remedy is being implemented as stated in the MNA Remedial Action Work Plan (DOE-ID 2003a)
- Monitoring data are being collected to determine peak TCE breakthrough for Zones 1 and 2 (see Section 3.1 for details)
- The requirements stated in the MNA Remedial Action Work Plan for determining the natural attenuation functional degradation mechanism have been met; therefore, no additional data must be collected in support of the mechanism (see Section 3.2 for details).

The ROD Amendment states that if evaluations show that the RAOs will not be met within this restoration timeframe, then the contingency remedy will be implemented. Evaluation of MNA implementation to the compliance and performance objectives stated in the MNA Remedial Action Work Plan (DOE-ID 2003b) demonstrates that the MNA component is operating as expected.

Table 4. Summary of performance and compliance monitoring requirements for monitored natural attenuation.

Performance Monitoring/Compliance Monitoring Summary					
Operations Phase	Monitoring Zone[a]	Performance Monitoring Requirements[b]	Compliance Monitoring Requirements[b]	Completion Criteria[c]	Key Deliverables[d]
Performance Operations	1	Annual monitoring for MNA performance parameters and upgradient radionuclides in accordance with the requirements stated in the Remedial Action Work Plan (DOE-ID 2003a)	Annual VOC and radiological monitoring in accordance with the Remedial Action Work Plan	Zone 1 will be operational and functional when (1) peak TCE breakthrough is exhibited in data before the numerical model-bounding estimate and (2) radiological data indicate attenuation sufficient to meet RAOs.	Model Verification Report Zone 1 Remedial Action Report
	2	Annual monitoring for MNA performance parameters in accordance with the requirements stated in the Remedial Action Work Plan	Annual VOC monitoring in accordance with the Remedial Action Work Plan	Zone 1 will be operational and functional when peak TCE breakthrough is exhibited in data before the numerical model-bounding estimate. Alternatively, the Agencies may determine Zone 2 to be operational and functional when (1) Zone 1 performance operations are complete and (2) a biodegradation mechanism has been demonstrated.	Zone 2 Remedial Action Report
Long-Term Operations	1	Monitoring frequency will be determined in the Remedial Action Report.	Monitoring frequency to be determined in the Remedial Action Report	Monitoring data verify that RAOs have been attained.	Operations, Maintenance, and Monitoring Report
	2	Monitoring frequency will be determined in the Remedial Action Report.	Monitoring frequency to be determined in the Remedial Action Report		
	3	The VOC monitoring will be performed once every 3 years. (If TCE in GIN-04 >10 μg/L, sampling will be increased to an annual basis; if TCE in TAN-56 >10 μg/L, a new well will be installed at the 30% downgradient location.)	VOC monitoring once every 3 years in accordance with the Remedial Action Work Plan		

Table 4. (continued).

Performance Monitoring/Compliance Monitoring Summary

Operations Phase	Monitoring Zone[a]	Performance Monitoring Requirements[b]	Compliance Monitoring Requirements[b]	Completion Criteria[c]	Key Deliverables[d]

a. Zone 1 wells are TAN-16, TAN-25, TAN-28, TAN-29, TAN-30A, TAN-37, TAN-51, TAN-54, TAN-55, and TSF-05.
Zone 2 wells are TAN-21, TAN-52, and ANP-8.
Zone 3 wells are GIN-4, TAN-56, TAN-57, and TAN-58.

b. Detailed monitoring requirements for each zone and phase were developed in accordance with the requirements of the *Guidance for the Data Quality Objectives Process* (EPA 2000b).

c. Decision rules for each zone and phase were developed in accordance with the requirements of the *Guidance for the Data Quality Objectives Process* (EPA 2000b).

d. Deliverables and schedules are described in greater detail in the MNA Remedial Action Work Plan (DOE-ID 2003a).

MNA = monitored natural attenuation
RAO = remedial action objective
TBD = to be determined
TCE = trichloroethene
VOC = volatile organic compound

3.1 Evaluation of Contaminant Concentrations

3.1.1 Evaluation of Trichloroethene Concentrations and Trends

Initial evaluations of MNA as a remedy for the distal portion of the plume indicated that TCE concentrations were being reduced relative to two internal tracers—tritium and tetrachloroethene (PCE) (DOE-ID 2003a). This was determined using a tracer-corrected method that utilizes internal tracers not affected by the aerobic cometabolism degradation mechanism to estimate degradation rate coefficients, while minimizing errors in the estimation as a result of nonbiological processes such as advection and dispersion. Using this method, the degradation half-life of TCE was from 9 to 21 years (Sorenson et al. 2000). An updated estimate of the TCE half-life using an expanded data set (including more recent groundwater monitoring data) is 13.2 years (DOE-ID 2003a). A period of time in which peak breakthrough of TCE will occur has been predicted for each MNA monitoring well using estimated degradation rates from the tracer-corrected method and numerical modeling.

The numerical TCE fate and transport model was calibrated based on the recommendations stated in the MNA Remedial Action Work Plan (DOE-ID 2003a). Using the calibrated numerical model, the period of time in which peak breakthrough will occur has been predicted in each well included in the MNA monitoring program. Three predictions were made for each well: one using the actual estimated half-life of 13.2 years and two conservative estimates using 14.7- and 20-year half-lives (DOE-ID 2003a; INEEL 2003). In most wells, the peak breakthrough predictions for this range of TCE degradation half-lives spanned a period of several years.

Evaluation of TCE concentration data and trends in Zone 1 wells (TAN-16, TAN-51, TAN-54, and TAN-55) indicates that MNA continues to trend toward meeting the RAOs. Observed concentrations will not exactly match predicted concentrations, resulting from recognized uncertainty of the model (DOE-ID 003a); however, the current data indicate trends toward RAOs. Based on the predicted peak breakthrough timeframes, peak TCE breakthrough in Zone 1 wells has already occurred or will be confirmed within the next 10 years. Peak breakthrough is predicted to occur in TAN-16 sometime between 2004 and 2006; however, the current data appear to demonstrate a possible TCE concentration peak in 1998, followed by a declining trend that occurred more recently than predicted (Figure 5). Continued groundwater monitoring at this location is necessary to either confirm continued decline to below the MCL or observe the actual peak breakthrough.

According to model predictions, peak breakthrough in the FLUTe™ wells in Zone 1 (TAN-51, TAN-54, and TAN-55) occurred before 2001. Data are insufficient to evaluate peak breakthrough in these Zone 1 wells, because groundwater monitoring in these wells began after the peak breakthrough period; monitoring began in 2001 for TAN-51 and 2002 for the other wells. Future groundwater monitoring of Zone 1 wells will be used to confirm a declining trend in TCE concentrations that would be expected after the occurrence of peak breakthrough.

Peak breakthrough in Zone 2 wells (TAN-21, TAN-52, and ANP-8) will occur in the future, as demonstrated in Figure 6. Analysis of breakthrough will occur for these wells in the future using statistical analyses of TCE concentrations to confirm a declining trend.

3.1.2 Evaluation of Plume Dimension Changes

Groundwater monitoring in Zone 3 wells (TAN-56, TAN-57, TAN-58, and GIN-4) suggests that there has been no significant plume expansion since Fiscal Year (FY) 2002. Detections of VOCs in TAN-56 would represent a 15% expansion along the axis of the plume, but no VOCs have been detected in TAN-56. Wells TAN-58 and TAN-57 are located cross-gradient from the toe of the plume, and no

VOCs have been detected in TAN-58. The TCE was detected in TAN-57 at concentrations below the MCL; however, the extent of the TCE groundwater plume in the vicinity of TAN-57 was previously unknown, so groundwater monitoring will be conducted again in FY 2005 to evaluate the extent of the plume and to determine if TCE concentrations are reproducible and/or increasing.

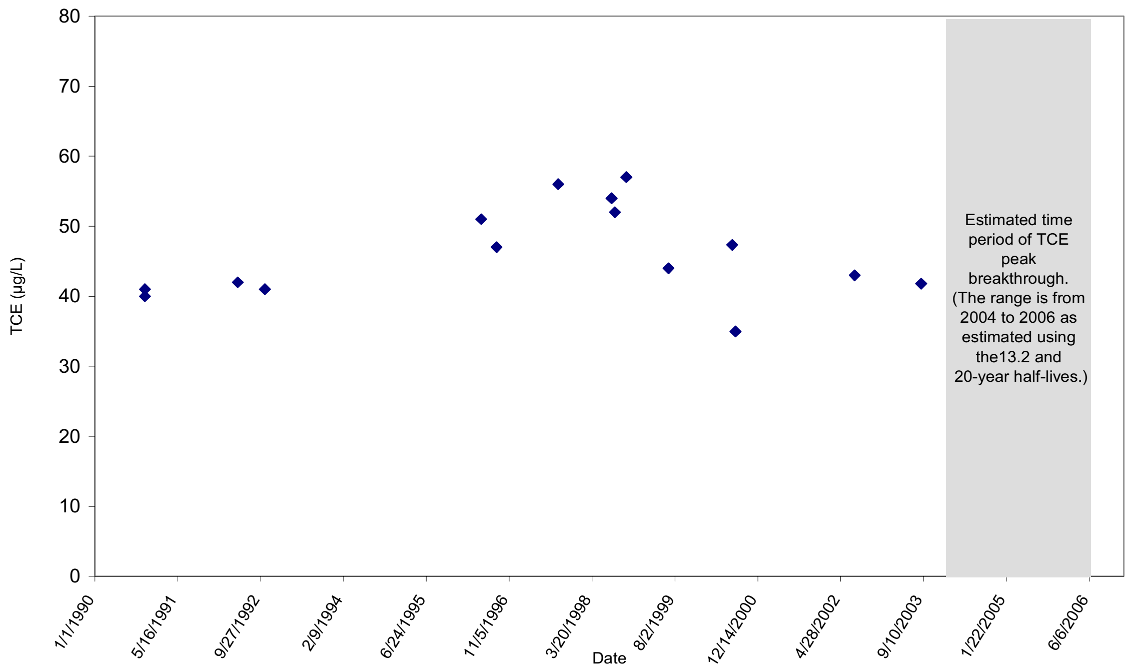

Figure 5. Trichloroethene peak breakthrough analysis in the TAN-16 well, Zone 1.

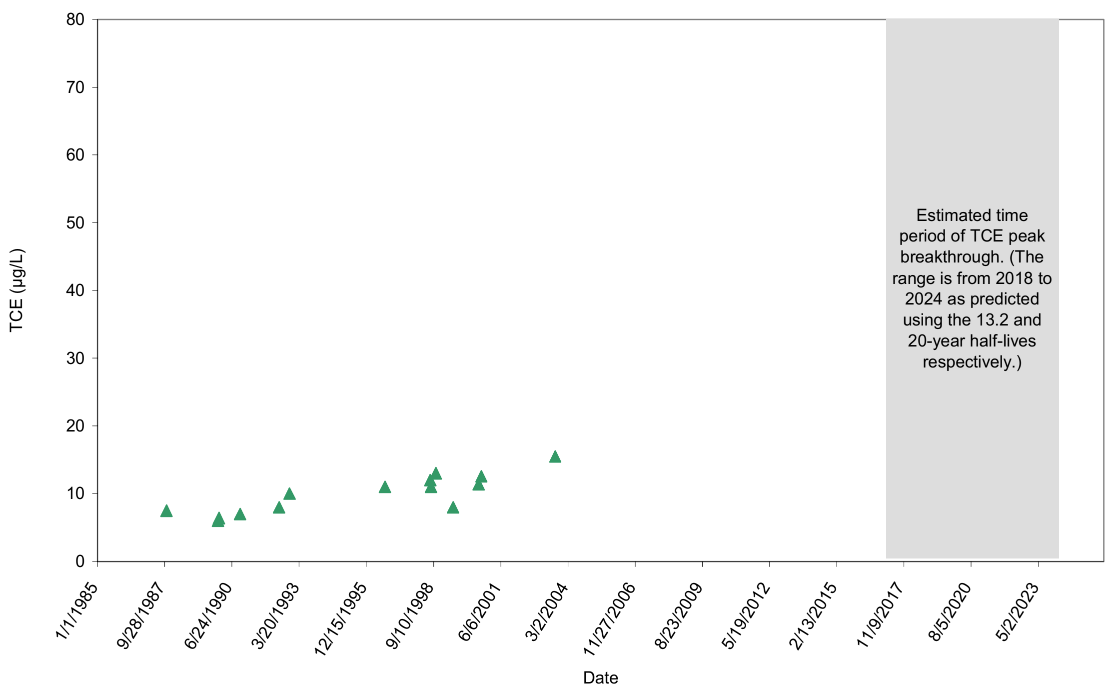

Figure 6. Trichloroethene peak breakthrough analysis in the ANP-8 well, Zone 2.

3.1.3 Quality Assurance and Quality Control

The quality assurance/quality control (QA/QC) requirements for the monitoring program were developed in the MNA Remedial Action Work Plan (DOE-ID 2003b) to meet the data quality objectives and to follow data quality requirements defined in the *Quality Assurance Project Plan for Waste Area Groups 1, 2, 3, 4, 5, 6, 7, 10, and Deactivation, Decontamination, and Decommissioning* (DOE-ID 2004a). The QA/QC requirements allow determination that all analytical results reported are accurate and adequate to ensure satisfactory execution of the MNA remedial component. To date, there have been no significant deviations from the QA/QC requirements to result in rejection of any data.

3.2 Natural Attenuation Degradation Mechanism

Activity-dependent enzyme probes targeting enzymes responsible for aerobic cometabolic degradation provide direct evidence that these mechanisms are active in the aquifer. These probes, which were first applied to TAN groundwater in 2002, only provide a positive signal if the enzyme is present and active. The resulting data provided the first direct evidence that the mechanism for aerobic cometabolic oxidation of chlorinated ethenes is present and active in the TAN distal zone of the aquifer. When applied to groundwater, the probes work by reacting with enzymes and result in a fluorescent product that can easily be seen under a microscope. If the appropriate enzyme is not present, or is present but not active in a given sample, then the probes will not be transformed into a fluorescent product. Two activity-dependent probes were applied: (a) the coumarin assay was used as a probe for soluble methane monooxygenase; and (b) 3-ethynyl-benzoate, 3 hydroxy-phenylacetylene, trans-cinnamonitrile, and phenylacetylene were used as toluene mono- and dioxygenase probes. In addition to the enzyme probing, several control studies were conducted to verify the detection of the cometabolic enzymes. Data from samples collected in FY 2003 demonstrated that toluene oxygenases and soluble methane monooxygenase are present and active both within the contaminant plume and outside the contaminant plume based on application of activity-dependent enzyme probes to groundwater samples. These results are consistent with conclusions from previous application of enzyme probes at TAN (Wymore, Harris, and Sorenson 2003). Based on these field and laboratory data, the degradation mechanism was identified as aerobic cometabolism by indigenous methanotrophs, propanotrophs, or phenol-oxidizers.

In addition to the detection of TCE-degrading enzymes, the primary substrate (i.e., methane), degradation by-products, and energy sources also were analyzed in TAN groundwater samples. Gas concentrations of methane, hydrogen, carbon monoxide, and ethane were monitored at the same well locations for which VOCs were analyzed. The presence of methane, hydrogen, oxygen, and carbon monoxide provides indirect evidence that TCE is being cometabolized (North Wind 2002; Wymore, Harris, and Sorenson 2003).

4. SUMMARY OF PROJECT COSTS AND ENFORCEABLE MILESTONES

This section addresses the cost, schedule, and deliverables for MNA remediation activities. The OU 1-07B ROD Amendment (DOE-ID 2001) cost estimate (see Table 5), and the assumptions contained in the ROD Amendment, may be used for cost comparisons throughout the project. Depending on the outcome of the specified ROD and Remedial Design/Remedial Action (RD/RA) Scope of Work decision points (DOE-ID 2002), the actual remediation costs have been within -30 to +50% of the ROD cost estimate. A cost comparison of the current project baseline and the cost estimate presented in the OU 1-07B ROD Amendment also are included.

Table 5. Operable Unit 1-07B remedial action cost summary.

Description	2004 Baseline Cost Estimate[a,b] (Using FY 1999 $)	ROD Amendment Cost Estimate[a] (FY 1999 $)
Monitored Natural Attenuation in the Distal Zone		
MNA Construction	42,100[c]	—
MNA Operations and Maintenance (FY 2004 to FY 2030)	676,726	709,804
Subtotal for MNA	718,826	709,804
Common Elements		
ISB Design	152,645	9,097
ISB Construction	1,178,936[d]	77,871
ISB Operations and Maintenance (FY 2004 to FY 2018)	1,761,059[e]	1,366,916
ISB Decontamination and Decommissioning	29,692	29,692
NPTF Design and Construction	1,910,599	1,787,000
NPTF Operations and Maintenance	2,005,987	946,130
Overall Facility Operations/Waste Management	6,488,003	4,273,770
GWTF Decontamination and Decommissioning	155,562	984,964
Miscellaneous Other Items	7,358,391	6,389,654
Subtotal for Common Elements	21,040,874	15,865,094
Total Costs Incurred through FY 1999	18,840,000	18,840,000
Total Cost	40,599,700	35,414,898
Contingency	3,102,647	8,287,449
TOTAL	43,702,347	43,702,347

a. Dollars are net present value with a discount rate of 7%.
b. The baseline cost estimate includes actual cost through FY 2004 and estimated costs for FY 2005 through FY 2031 (except as noted).
c. Includes cost of FLUTe™ liner in FY 2003. This cost was not included in the ROD Amendment cost estimate (DOE-ID 2001).
d. Includes cost for office space, installation of additional monitoring and injection wells, construction of nutrient storage locations, and development of separate work plans in accordance with the ISB Remedial Action Work Plan (DOE-ID 2004c). These costs were not included in the ROD Amendment cost estimate (DOE-ID 2001).
e. The ISB operations and maintenance cost included alternate electron donor testing and evaluation.

FY = fiscal year
ISB = in situ bioremediation
MNA = monitored natural attenuation
NPTF = New Pump and Treat Facility
ROD = Record of Decision

Table 6 identifies the documents and deliverables that are required by the Agencies for the MNA remedial component. This table identifies the document, document type, planned and enforceable due dates, and the date the document was actually submitted. To date, all required documents and deliverables for the MNA remedial component have been delivered on or ahead of schedule.

Table 6. Agency deliverable documents.

Deliverable	Planned Submittal Date	Enforceable Submittal Date	Review Duration (days)	Document Type
MNA Remedial Action Work Plan	January 2003	March 2003	45	Primary
MNA Prefinal Inspection Report	December 2003	March 2004	45	Primary
MNA Modeling Verification Report	September 2005	Not applicable	30	Secondary
Zone 1 Remedial Action Report	July 2013	September 2013	45	Primary
Zone 2 Remedial Action Report[a]	To be determined	To be determined	45	Primary
Operations, Monitoring, and Maintenance Plan, Revision[a]	To be determined	To be determined	45	Primary
MNA Annual Performance Report	July/yearly	Not applicable	INFO	External release
Operations, Monitoring, and Maintenance Report[a]	To be determined	To be determined	45	Primary

a. Deliverable date (to be determined) set in the MNA Zone 1 Remedial Action Report.

FY = fiscal year
INFO = for information
ISB = in situ bioremediation
MNA = monitored natural attenuation

5. OBSERVATIONS AND LESSONS LEARNED

Observations and lessons learned during selection and implementation of the MNA remedial component are stated in this section. Determining the effectiveness of MNA for this site and gaining acceptance of the MNA remedial component required multiple lines of evidence. Integration of these multiple lines of evidence was a critical component in determining that MNA is an effective remedial component for the distal zone. Standard practices for applying MNA had not yet been developed when the selection was made, so the required evidence was gathered by identifying the necessary lines of evidence and then systematically applying forefront-of-science methods using rigorous controls to ensure that the method results were accurate. The techniques identified and successfully applied during the process included:

- **The Tracer-Corrected Method**—Used to demonstrate TCE concentration reduction and establish the rate of change of contaminant concentrations (Section 5.1)

- **Activity-Dependent Enzyme Probes—**Used to directly confirm the presence of an aerobic mechanism of degradation, which was indirectly supported by dissolved gas monitoring (Section 5.2)

- **Vertical Profile Sampling—**Used to understand vertical contaminant distribution and confirm trends and mechanisms that support MNA (Section 5.3).

5.1 Rate of Change in Contaminant Concentrations

Monitored natural attenuation was evaluated using the tracer-corrected method, which demonstrated that TCE concentrations were being reduced relative to two internal tracers, tritium and PCE (DOE-ID 2003a). This method utilizes internal tracers that are not affected by the aerobic cometabolic degradation mechanisms to estimate degradation rate coefficients, while minimizing errors in the estimation as a result of nonbiological processes such as advection and dispersion. Using estimated degradation rates from the tracer-corrected method and numerical modeling, a period of time in which peak breakthrough of TCE will occur has been predicted in each MNA monitoring well.

The resulting estimates of degradation rate and peak breakthrough times are significant pieces of evidence that the MNA remedial component will meet cleanup objectives. In addition, these estimates are useful in making operational decisions concerning groundwater monitoring, which is a key component of any MNA remedy. Rapid change in contaminant concentrations within the groundwater is not expected for this MNA remedial component. Therefore, having established predictions of degradation rate and peak breakthrough are key components to periodic assessment of MNA performance relative to cleanup goals throughout the remediation timeframe.

Lesson Learned: The tracer-corrected method for estimating the rate of contaminant concentration change and numerical modeling using that rate to estimate peak breakthrough times provides key evidence for the effectiveness of MNA and provides important information for the monitoring component of an MNA remedy.

5.2 Aerobic Mechanism Investigations

Natural processes of attenuation include dispersion, dilution, sorption, volatilization, transformation, and biodegradation. However, processes that degrade or destroy contaminants are preferred for implementation of an MNA remedy (EPA 1999). As part of the MNA field evaluation, aerobic biodegradation mechanisms were investigated since groundwater in the distal zone is generally aerobic. The application of enzyme probes (as direct evidence) and dissolved gas monitoring (as indirect evidence) provided results that strongly indicated TCE was being degraded aerobically by the process of cometabolism. Groundwater samples were collected from several locations both inside and outside the TCE plume and included vertically discrete sampling locations (Section 5.3). Activity-dependent enzyme probes are analytical tools, which directly demonstrate that enzymes responsible for cometabolism are present and active in a groundwater sample. The application of these probes to TAN groundwater samples demonstrated the presence and activity of the cometabolic degradation mechanism for TCE within and outside the TAN distal zone (Wymore, Harris, and Sorenson 2003; DOE-ID 2004d). Indirect evidence included analyzing groundwater samples for the dissolved gases (hydrogen, oxygen, and methane) that are primarily responsible for the induction and generation of the cometabolic enzyme. The presence of these gases supports the findings that these enzymes are active in TAN distal zone groundwater. Providing both direct and indirect evidence of this cometabolic mechanism was the key component in gaining acceptance of the MNA remedy for the TAN distal zone.

Lesson Learned: For large aerobic TCE plumes, such as the TAN distal zone, aerobic mechanisms likely are the primary mode of intrinsic biological degradation for an MNA remedy. Enzyme probes and other indirect evidence have demonstrated that aerobic mechanisms of TCE biodegradation are significant and active.

5.3 Utility of Vertical Profile Sampling

Effective groundwater monitoring is imperative to the MNA remedial component. Vertical profile sampling provides an understanding of the vertical extent, in addition to the areal extent, of the groundwater plume. Several MNA monitoring wells were designed to sample groundwater at discrete depths. Generating vertical profiles of contaminants allowed for development of a more accurate description of the overall redox conditions in the TAN distal zone, defining the extent of the plume, confirming the method used to estimate degradation rates, and defining zones of enzyme activity

(Wymore, Harris, and Sorenson 2003; DOE-ID 2004d). Routine sampling from these vertically discrete sampling wells continues to support effective monitoring of the groundwater plume within the distal zone. Data collected from both vertical profiling wells and non-profiled wells are used to evaluate peak breakthrough; however, the addition of vertically discrete sampling locations confirms that the observations are consistent throughout the depth of the plume.

Lesson Learned: Vertically discrete sampling provides data for development of an MNA remedy that accounts not only for the areal extent but also the vertical extent of the plume. These data are useful for validating evidence supporting that the MNA remedy is consistent with respect to depth in the plume.

6. CONTACT INFORMATION

Table 7 provides contact information for project managers affiliated with the EPA, DOE, DEQ, and the major design and remediation contractor, CH2M-WG Idaho, LLC.

Table 7. List of project managers with contact information.

Name	Affiliation	Address	Phone Number
Lee Nelson	CH2M-WG Idaho, LLC (design and remediation contractor) project manager	PO Box 1625, Mail Stop 3940 Idaho Falls, Idaho 83415	(208) 526-3093
Matt Wilkining	EPA project manager	1435 North Orchard Street Boise, ID 83706	(208) 378-5760
Margie English	DEQ project manager	1410 North Hilton Boise, ID 83706-1255	(208) 373-0306
Mark Shaw	DOE project manager	PO Box 1625 Mail Stop 1222 Idaho Falls, Idaho 83415	(208) 526-6442

DEQ = (Idaho) Department of Environmental Quality
DOE = U.S. Department of Energy
EPA = U.S. Environmental Protection Agency

7. REFERENCES

40 CFR 300.435, 2005, "Remedial Design/Remedial Action, Operation and Maintenance," *Code of Federal Regulations*, Office of the Federal Register, August 10, 2005.

42 USC § 6901 et seq., 1976, "Resource Conservation and Recovery Act (Solid Waste Disposal Act)," *United States Code*, October 21, 1976.

42 USC § 9601 et seq., 1980, "Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA/Superfund)," *United States Code,* December 11, 1980.

DOE-ID, 1987, *Consent Order and Compliance Agreement,* Document ID 1085-10-07-3008, Rev. 0, U.S. Department of Energy Idaho Operations Office; U.S. Environmental Protection Agency, Region 10; and U.S. Geological Survey, July 1987.

DOE-ID, 1991, *Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory,* Administrative Docket No. 1088-06-29-120, U.S. Department of Energy Idaho Operations Office; U.S. Environmental Protection Agency, Region 10; Idaho Department of Health and Welfare, December 4, 1991.

DOE-ID, 1995, *Record of Decision Declaration for the Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites Final Remedial Action,* Document ID 10139, U.S. Department of Energy Idaho Operations Office; U.S. Environmental Protection Agency, Region 10; and Idaho Department of Health and Welfare, August 1995.

DOE-ID, 1997a, *Technology Evaluation Work Plan Test Area North Final Groundwater Remediation Operable Unit 1-07B*, DOE/ID-10562, Rev. 0, U.S. Department of Energy Idaho Operations Office, March 1997.

DOE-ID, 1997b, *Remedial Design/Remedial Action Scope of Work Test Area North Final Groundwater Remediation Operable Unit 1-07B,* DOE/ID-10522, Rev. 5, U.S. Department of Energy Idaho Operations Office, August 1997.

DOE-ID, 1998, *Natural Attenuation Field Evaluation Work Plan for Test Area North Final Groundwater Remediation, Operable Unit 1-07B*, DOE/ID-10606, Rev. 0, U.S. Department of Energy Idaho Operations Office, February 1998.

DOE-ID, 2000, *Field Demonstration Report, Test Area North Final Groundwater Remediation, Operable Unit 1-07B,* DOE/ID-10718, Rev. 0, U.S. Department of Energy Idaho Operations Office, March 2000.

DOE-ID, 2001, *Record of Decision Amendment Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites, Final Remedial Action*, DOE/ID-10139, Rev. 0, U.S. Department of Energy Idaho Operations Office, September 2001.

DOE-ID, 2002, *Remedial Design/Remedial Action Scope of Work Test Area North Final Groundwater Remediation Operable Unit 1-07B*, DOE/ID-10905, Rev. 1, U.S. Department of Energy Idaho Operations Office, November 2002.

DOE-ID, 2003a, *Monitored Natural Attenuation Remedial Action Work Plan for Test Area North Final Groundwater Remediation, Operable Unit 1-07B*, DOE/ID-11055, Rev. 0, U.S. Department of Energy Idaho Operations Office, June 2003.

DOE-ID, 2003b, *Monitored Natural Attenuation Operations, Monitoring, and Maintenance Plan for Test Area North, Operable Unit 1-07B*, DOE/ID-11066, Rev. 0, U.S. Department of Energy Idaho Operations Office, June 2003.

DOE-ID, 2004a, *Quality Assurance Project Plan for Waste Area Groups 1, 2, 3, 4, 5, 6, 7, 10, and Deactivation, Decontamination, and Decommissioning*, DOE/ID-10587, Rev. 8, U.S. Department of Energy Idaho Operations Office, March 2004.

DOE-ID, 2004b, *INEEL Sitewide Institutional Controls Plan*, DOE/ID-11042, Rev. 1, U.S. Department of Energy Idaho Operations Office, June 2004.

DOE-ID, 2004c, *In Situ Bioremediation Remedial Action Work Plan for Test Area North Final Groundwater Remediation, Operable Unit 1-07B*, DOE/ID-11015, Rev. 2, U.S. Department of Energy Idaho Operations Office, July 2004.

DOE-ID, 2004d, *Monitored Natural Attenuation 2003 Performance and Compliance Monitoring Annual Report for Test Area North Operable Unit 1-07B*, DOE/NE-ID-11148, Rev. 0, U.S. Department of Energy Idaho Operations Office, June 2004.

EPA, 1999, *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites,* OSWER Directive 9200.4-17P, http://www.epa.gov/swerust1/directiv/d9200417.pdf, April 1999.

EPA, 2000a, *Close-Out Procedures for National Priorities List Sites*, EPA 540-R-98-016, OSWER Directive 9320.2-09A-P, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, January 2000.

EPA, 2000b, *Guidance for the Data Quality Objectives Process*, EPA QA/G-4, EPA/600/R-96/055, U.S. Environmental Protection Agency, August 2000.

EPA, 2001, *Operation and Maintenance in the Superfund Program*, EPA 540-F-01-004, OSWER Directive 9200.1-37FS, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, May 2001.

ICP, 2004, *Monitored Natural Attenuation Final Inspection Report*, ICP/EXT-03-00089, Rev. 0, Idaho Completion Project, January 2004.

ICP, 2005a, *Test Area North Operable Unit 1-07B Final Groundwater Remedial Action Health and Safety Plan*, INEEL/EXT-99-00020, Rev. 3, Idaho Cleanup Project, July 2005.

ICP, 2005b, *Waste Management Plan for Test Area North Final Groundwater Remediation Operable Unit 1-07B*, INEEL/EXT-98-00267, Rev. 5, Idaho Completion Project, April 2005.

INEEL, 1997, *Explanation of Significant Differences from the Record of Decision for the Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites, Final Remedial Action, Operable Unit 1-07B, Waste Area Group 1,* INEEL/EXT-97-00931, Rev. 0, Idaho National Engineering and Environmental Laboratory, November 1997.

INEEL, 1999, *Numerical Modeling Support of the Natural Attenuation Field Evaluation for Trichloroethene at the Test Area North, Operable Unit 1-07B, Idaho National Engineering and Environmental Laboratory*, INEEL/EXT-97-01284, Rev. 1, Idaho National Engineering and Environmental Laboratory, January 1999.

INEEL, 2002, *Interim Decontamination Plan for Operable Unit 1-07B,* INEEL/EXT-97-01287, Rev. 4, Idaho National Engineering and Environmental Laboratory, May 2002.

INEEL, 2003, *2003 Update to the Test Area North Large-Scale Groundwater Flow and Transport Model for the Assessment of Monitored Natural Attenuation,* INEEL/INT-03-00709, Rev. 0, Idaho National Engineering and Environmental Laboratory, November 2003.

INEL, 1994, *Remedial Investigation Final Report with Addenda for the Test Area North Groundwater Operable Unit 1-07B at the Idaho National Engineering Laboratory*, EGG-ER-10643, Rev. 0, Volumes 1 and 2, Idaho National Engineering Laboratory, January 1994.

North Wind, 2002, *Final Accelerated Site Technology Deployment Vertical Profile Sampling Report,* NWE-ID-2002-055, Rev. 0, North Wind, Inc.

Sorenson, K. S., L. N. Peterson, R. L. Ely, and R. E. Hinchee, 2000, "An Evaluation of Aerobic Trichloroethene Attenuation Using First-Order Rate Estimation," *Bioremediation Journal*, 4(4): 337-358.

Wymore, R. A., K. L. Harris, and K. S. Sorenson, 2003, *Final Quick Win Vertical Profile Sampling Report*, NWE-ID-2003, Rev. 0, North Wind, Inc.

Appendix A

Monitoring Well Information

Table A-1. Monitoring well information.

Zone	Well	Total Well Depth (ft bls)	Production Interval (ft bls)	Screen Type	Screen Material	Sampling Depth	Depth to Water Table Following Well Construction (year)	Depth to Water Table in June 2004
1	TAN-16	323	302–322	Stainless steel	Stainless steel	307	202 (1990)	218.16
1	TAN-51[a]	470	NA	Open hole	NA	240	211 (1999)	217.52
						263		
						283.5		
						322		
						342		
						342[b]		
						367		
						413		
						460		
1	TAN-54[a]	474.00	NA	Open hole	NA	234	213.74 (2000)	218.60
						318		
						330.5		
						347		
						373		
						394		
						420		
						460		
1	TAN-55[a]	470	NA	Open hole	NA	221	213.28 (2000)	218.52
						251		
						265		
						317		
						332		
						373.5		
						404		
						439		
						449		
						461		

Table A-1. (continued).

Zone	Well	Total Well Depth (ft bls)	Production Interval (ft bls)	Screen Type	Screen Material	Sampling Depth	Depth to Water Table Following Well Construction (year)	Depth to Water Table in June 2004
1	TAN-25	315	217–297	Slotted	Stainless steel	218	205.3 (1993)	206.78 (1997)[c]
1	TAN-28	262	220–260	Slotted	Stainless steel	240	206.55 (1994)	212.89
1	TAN-29	265	222.25–262.25	Slotted	Stainless steel	253	207.11 (1994)	212.81
1	TAN-30A	320.90	300–320	Slotted	Stainless steel	313	206.85 (1994)	212.81
1	TAN-37	415.90	204–416	Open hole	NA	240	206.37 (1998)[d]	213.05
				Open hole	NA	270		
1	TSF-05	310	180–344	Perforated	Steel	235	199.25 (1953)	211.84
			269–305	Perforated	Steel	270		
2	TAN-21	519.50	431–451	Stainless steel	Stainless steel	432	211.33 (1992)	219.62
2	ANP-8	309.20	232.8–304.65	Perforated	Steel	268	209.31 (1956)	222.59
2	TAN-52[a]	470	NA	Open hole	NA	220	211 (1999)	219.24
						242		
						266		
						303		
						361		
						373		
						395		
						438		
						456		
3	GIN-4	300	287–297	Slotted	PVC	292	208.9 (1964)	218.58
3	TAN-56[a]	460	NA	Open hole	NA	223	215.73 (2000)	221.02
						242		
						275		
						334		
						387		

Table A-1. (continued).

Zone	Well	Total Well Depth (ft bls)	Production Interval (ft bls)	Screen Type	Screen Material	Sampling Depth	Depth to Water Table Following Well Construction (year)	Depth to Water Table in June 2004
						403		
						454		
3	TAN-57	491	221–491	Open hole	NA	353	218.6 (2000)	224.26
3	TAN-58	483	220–483	Open hole	NA	295	216.62 (2000)	222.44

a. FLUTe liners are installed in these wells with sampling ports at the listed sampling depths.
b. TAN-51 has two sample ports at a depth of 342 ft.
c. Last reported water level for TAN-25 was measured in 1997.
d. The water level was not measured following TAN-37 well construction in 1997, so the reported water level is one year after construction in 1999.

NA = not applicable
PVC = polyvinyl chloride

Appendix B

Final Inspection Details

Appendix B

Final Inspection Details

During the monitored natural attenuation (MNA) prefinal inspection, it was observed that all four wells that were inspected had a locked cap on the exterior casing; however, the interior casings were not capped. The Idaho Department of Environmental Quality (DEQ) requested that all interior well casings be capped. Table B-1 summarizes the corrective actions completed for all wells used for monitoring at Test Area North (TAN). Since all exterior casings were capped and locked, this table refers only to interior casings. Wells used for MNA monitoring under the MNA Operations, Monitoring, and Maintenance Plan (DOE-ID 2003b) are highlighted.

Table B-1. Operable Unit 1-07B distal zone monitoring well interior casing and cap status.

Well	Corrective Action
ANP-5[a]	No action needed.
ANP-6[a]	No action needed.
ANP-7[a]	No action needed.
ANP-8	Installed 1-in. and 3-in. flat caps.
ANP-91	No action needed.
ANP-101	No action needed.
FET Disposal	No action needed.
GIN-1	Installed a cap over inside pipe.
GIN-2	Installed a cap over inside pipe.
GIN-3	Installed a cap over inside pipe.
GIN-4	Installed a cap over inside pipe.
GIN-5	Installed a cap over inside pipe.
MW-2	Installed existing cap.
NONAME	No action needed.
OWSLEY-21	No action needed.
P&W 11	No action needed.
P&W 21	No action needed.
P&W 31	No action needed.
PSTF	No action needed.
TANT-MON-A-01	Small hole in landing plate for pump power supply was sealed.
TAN-04	Small hole in landing plate for pump power supply was sealed.
TAN-05	Small hole in landing plate for pump power supply was sealed.
TAN-06	Small hole in landing plate for pump power supply was sealed.
TAN-07	Small hole in landing plate for pump power supply was sealed.
TAN-08	Small hole in landing plate for pump power supply was sealed.
TAN-09	Small hole in landing plate for pump power supply was sealed.
TAN-10	Installed a cap over inside pipe.
TAN-10A	Small hole in landing plate for pump power supply was sealed.

Table B-1. (continued).

Well	Corrective Action
TAN-11	Small hole in landing plate for pump power supply was sealed.
TAN-12	Small hole in landing plate for pump power supply was sealed.
TAN-13A	Small hole in landing plate for pump power supply was sealed.
TAN-14	Small hole in landing plate for pump power supply was sealed.
TAN-15	Small hole in landing plate for pump power supply was sealed.
TAN-16	Small hole in landing plate for pump power supply was sealed.
TAN-17	Installed a 1-3/4-in. cap.
TAN-18	Small hole in landing plate for pump power supply was sealed.
TAN-19	Small hole in landing plate for pump power supply was sealed.
TAN-20	Small hole in landing plate for pump power supply was sealed.
TAN-21[2]	Small hole in landing plate for pump power supply was sealed.
TAN-22A	Small hole in landing plate for pump power supply was sealed.
TAN-23A	Small hole in landing plate for pump power supply was sealed.
TAN-24A	Installed existing cap.
TAN-25	No action needed.
TAN-26	No action needed.
TAN-27	Small hole in landing plate for pump power supply was sealed.
TAN-28	Installed a 2-in. cap.
TAN-29	Small hole in landing plate for pump power supply was sealed.
TAN-30A	Installed a 2-in. cap.
TAN-31	Installed a notch cut in lid for EZ-Reel.
TAN-32	Installed a 4-in. cap.
TAN-33	Inner 10-in. casing has a half landing plate for hose and power supply. The casing was capped.
TAN-34	Installed an 8-in. cap.
TAN-35	Installed an 8-in. cap.
TAN-36	Inner 10-in. casing has a half landing plate for hose and power supply. The casing was capped.
TAN-37	No action needed.
TAN-38	No action needed.
TAN-39	No action needed.
TAN-40	No action needed.
TAN-41	Installed a 6-in. cap on inner casing.
TAN-42	Installed a 4-in. cap on inner casing.
TAN-43	Inner 6-in. casing has a half landing plate for hose and power supply. The casing was capped.
TAN-44	Inner 6-in. casing has a half landing plate for hose and power supply. The casing was capped.
TAN-45	A 6-in. inner casing with Mini-troll was down-hole. The casing was capped.
TAN-46	Installed a 6-in. cap on inner casing.

Table B-1. (continued).

Well	Corrective Action
TAN-47	Installed a 10-in. cap on inner casing.
TAN-48	Installed a 1/2-in. cap on pipe. The fittings were replaced on FLUTe™ lines.
TAN-49	Installed a 10-in. cap on inner casing.
TAN-50	Installed a 10-in. cap on inner casing.
TAN-51[b]	Installed a 1/2-in. cap on water level pipe.
TAN-52[b]	Installed a 1/2-in. cap on water level pipe.
TAN-54[b]	Installed a 1/2-in. cap on water level pipe.
TAN-55[b]	Installed a 1/2-in. cap on water level pipe.
TAN-56[b]	Installed a 1/2-in. cap on water level pipe.
TAN-57	Installed a 10-in. cap on inner casing.
TAN-58	Installed a 10-in. cap on inner casing.
TAN-CH2 Mon. 1	Installed two 1-in. caps.
TAN-CH2 Mon. 2	No action needed.
TAN-D1[c]	No action needed.
TAN-D2[c]	No action needed.
TAN-D3[c]	No action needed.
TSF-05	Installed a 4-in. flat cap.
USGS-07	No action needed.
USGS-24	No action needed.
USGS-25	No action needed.
USGS-26	No action needed.
TAN-1859	No action needed.
TAN-1860	Installed a 10-in. cap on inner casing.
TAN-1861	Installed a 10-in. cap on inner casing.

a. These wells were completed with exterior casing only.
b. These are FLUTe™ wells.
c. These wells are stormwater injection wells. They are equipped with a wire mesh cap.